# §11. Period of the Macroscopic Oscillation of Detached Plasma in the TPD-II

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The baffled/closed divertor configuration, the neutral leakage through the opening of the baffle expected to be reduced by friction due to ion-neutral collisions. The friction effectively decreases the gas conductance of the opening, which is the so-called "plasma plugging" effect. This effect depends on the position of the detachment front, $z_f$, since if $z_f$ is outside the divertor region, the plasma pressure at the inlet of divertor region is lost and along with the friction holding the neutrals backs.

The stability of the detached plasma was experimentally investigated in a linear machine, TPD-II (Test Plasma by Direct current) with a baffle. As shown in Fig. 1, the baffle plate partitioned the experimental space into two regions: a low-neutral-pressure region and a high-neutral-pressure region, labeled the edge plasma (E) and divertor (D) regions, respectively. It was observed that when helium gas was injected into the D region, $z_f$ oscillated between the D and E regions.[1] The back-and-forth motion of $z_f$ was accompanied by a significant oscillation of neutral gas pressures in the E and D regions. Here, we report that the period of the oscillation is closely related to the plasma plugging effect. [2]

As schematically shown in Fig. 1, the helium plasma enters the E region first and then the D region. The orifice (15 mm in length and 15 mm in diameter somewhat larger than the plasma diameter) is the equivalent of divertor opening in magnetic confinement devices. The axial magnetic field was 0.2 T and the discharge current was 95 A. The electron plasma density was $10^{19}$ $m^{-3}$ and the electron temperature was 6 eV, which was obtained by a Langmuir probe located in the E region at 0.2 m from the orifice under the condition without gas injection into the D region. Neutral gas was injected to cause plasma detachment into the D region, and is pumped at the E region. The neutral gas pressures at the D and E regions, $P_D$ and $P_E$, were measured using baratron gauges.

Figure 2(a) shows the typical $P_D$-oscillation accompanied by the back-and-forth motion of $z_f$. There are two parts in the cycle: the slow rise and the rapid fall. The first part begins after $z_f$ suddenly changes to the D region. The increase in $P_D$ is a transient; we postulate that $P_D$ increases toward the saturation value, $P_{DS}$, given by $P_{DS} = P_E + Q_D/C_{eff}$, where $C_{eff}$ is the effective orifice-conductance decreased by the plasma flow coming into the D region at the beginning of the first part of the oscillation, and $Q_D$ is the flow late of the injection gas. If the transient waveform is described simply as $P_D = P_{DS} - (P_{DS} - P_{D0}) \exp\{-(t-t_0)/\tau\}$ (where $P_{D0}$ is the initial pressure for $t = t_0$), the mean time-constant $\tau$ is given by $\tau = V_D/C_{eff}$,, where $V_D$ is the volume of the D region.

The second part of the oscillation begins after $z_f$ enters the E region. In this part, $P_E$ experiences a sudden increase and decrease, and $P_D$ decreases rapidly. This clearly shows that the neutral gas accumulated in the D region flows into the E region, which is due to the enhancement of $C_{eff}$, i.e., the disappearance of plasma plugging when $z_f$ changes to the E region.

Figure 2(b) shows comparison between the duration of the first part, $t_1$, and mean time-constant $\tau$ (described before) for various discharge currents $I_d$ and gas species. In order to estimate the value of $\tau$, we derive the value of $C_{eff}$ from the mean slope, $<\partial\Delta P/\partial Q_D>$ [where $\Delta P = P_D - P_E$] corresponding each experimental condition. From Fig. 2(b), we can see that $t_1$ and $\tau$ behave in a similar way, suggesting that the period of the oscillation depends on the plasma plugging effect.

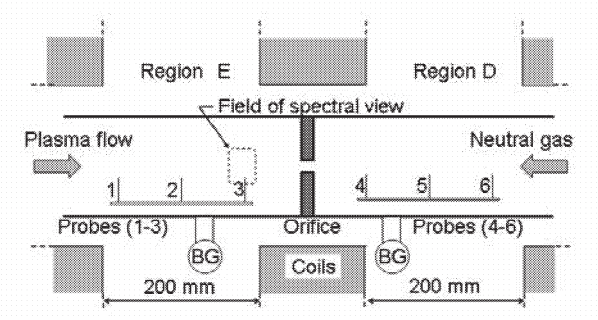


Fig. 1. Schematic of experimental region of the TPD-II.

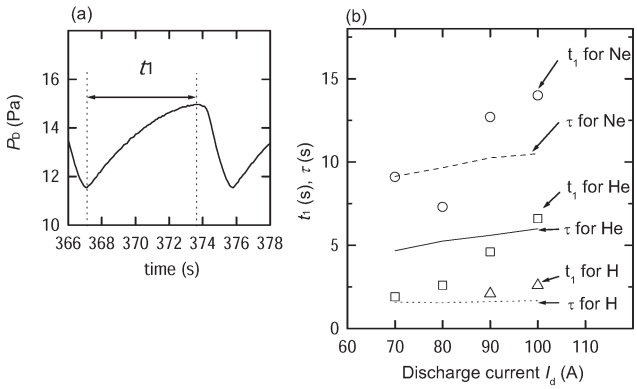


Fig. 2. Typical $P_D$-oscillation (a), and comparison between $t_1$ and $\tau$.

[1] Matsubara, A., et al., J. Plasma Fusion Res. 78, 196 (2002).
[2] Matsubara, A., et al., J. Nucl. Mater. **337-339**, 181 (2005).